



UNIVERSITI PUTRA MALAYSIA

**TIME-UNCERTAINTY ANALYSIS BY USING SIMULATION
IN PROJECT SCHEDULING NETWORKS**

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**TIME-UNCERTAINTY ANALYSIS BY USING SIMULATION
IN PROJECT SCHEDULING NETWORKS**

By

ANWAR MOHAMMED OMER

**Thesis Submitted in Partial Fulfilment of the Requirements for
the Degree of Master of Civil Engineering
in the Faculty of Engineering
Universiti Putra Malaysia**

December 1999



*Dedicated to my late mother,
Mariam Mohd Al-Adar,
May Allah (s.w.t) rest her soul in peace.*



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in partial fulfilment of the requirements for the degree of Master of Science

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in Project Scheduling Networks**

By

Anwar Mohammed Omer

December 1999

Chairman : **L. Jawahar Nesan, Ph.D.**

Faculty : **Engineering**

Risks are inherently present in all construction projects. Quite often, construction projects fail to achieve their time quality and budget goals. Risk management is a subject, which has grown in popularity during the last decade. It is a formal orderly process for systematically identifying, analysing and responding to risks associated with construction projects so as to reduce the effects of these risks to an acceptable level. Risk analysis is primarily concerned with evaluating uncertainties. The purpose of risk analysis is to enable a decision-maker to take an appropriate response in advance against a possible occurrence of a problem. In this study, Monte Carlo simulation as a tool of risk analysis was used.

The merge event bias as one of the essential problems associated with PERT is discussed, along with models and approaches developed by other

researchers, namely, Probabilistic Network Evaluation Technique (PNET algorithm), Modified PNET, Back-Forward Uncertainly Estimation procedure (BFUE) and concept based on the robust reliability idea. These developed approaches are more reliable in planning construction projects compared to PERT because they attempt to handle the merge event bias problem.

In addition, this study demonstrates a number of benefits, the most significant among them being that: (1) Formal risk management techniques are rarely used in construction. Dealing with risk management in construction is now essential for minimizing losses and to enhance profitability. (2) It is very dangerous to rely only on PERT/CPM conventional techniques in scheduling projects. (3) To use floats, as stated by traditional resource allocation method, is not practicable. (4) For a project network, the likelihood completion date of a project is exactly equal to the product of the probabilities of each path, separately, with respect to a project completion date. Using simulation now validates this statement. (5) The computation error of a project likelihood completion date is less than 10 percent if a path of a float greater than twice the larger standard deviation of this mentioned path and the critical path is dropped from the calculation, and (6) An effective risk response framework is introduced to help contractors systematically manage the risk in scheduling their projects.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian daripada keperluan untuk Ijazah Master Sains

**Analisis Waktu-Taktentu Dengan Menggunakan Simulasi
Dalam Jaring Projek Penjadualan**

Oleh

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Risiko wujud secara semulajadi dalam projek-projek pembinaan. Projek pembinaan seringkali gagal mencapai kualiti masa dan peruntukan yang telah ditetapkan. Pengurusan risiko merupakan suatu subjek yang berkembang dengan popular sejak dekad yang lepas. Ia merupakan proses formal yang teratur bagi mengenalpastian secara sistematik, analisis dan respon terhadap risiko yang berkaitan dengan projek-projek pembinaan serta untuk mengurangkan kesan risiko-risiko ini kepada paras yang sepatutnya. Analisis risiko sangat penting dalam menilai ketidakpastian. Tujuan analisis risiko ialah untuk membolehkan pembuat keputusan memberi respon sebaik-baiknya dengan lebih awal bagi mengelakkan

masalah yang akan wujud. Dalam kajian ini, simulasi Monte Carlo sebagai alat untuk analisis risiko telah digunakan.

'**The merge event bias**' yang merupakan masalah utama berkaitan dengan PERT dibincangkan bersama model-model dan pendekatan yang dibangunkan oleh para penyelidik, ialah, '**Probabilistic Network Evaluation Technique (PNET algorithm), Modified PNET, Back-Forward Uncertainly Estimation procedure (BFUE)**' dan konsep berasaskan idea yang bernas dan boleh dipercayai. Pendekatan yang berkembang ini lebih dirujuk dalam merancang projek-projek pembinaan berbanding PERT kerana ia cuba menyelesaikan masalah '**merge event bias**'.

Di samping itu, kajian ini juga menunjukkan beberapa kebaikan dan yang paling signifikan antaranya yakni: (1) teknik-teknik pengurusan risiko yang formal jarang digunakan dalam pembinaan. Berurusan dengan pengurusan pembinaan yang berisiko kini ternyata dapat meminimum kerugian dan mempertingkatkan keuntungan. (2) merbahaya sekiranya bergantung hanya kepada teknik PERT/CPM yang konvensional dalam menjadual projek. (3) menggunakan jalur lebih masa seperti dinyatakan dengan kaedah penumpuan sumber tradisional. (4) bagi suatu jaring projek, tarikh matang kebolehjadian suatu projek ialah sama dengan hasil dari peluang pada setiap jalur secara terpisah dengan merujuk kepada tarikh matang projek. Kenyataan ini kini telah disahkan dengan penggunaan simulasi. (5) ralat penghitungan dari tarikh matang kebolehjadian suatu projek hanya kurang daripada

10 peratus jika suatu jalur lebih masa adalah lebih besar daripada dua kali ganda simpangan baku terbesar dari jalur tersebut dan jalur genting dikesampingkan dari penghitungan, dan (6) rangka kerja respon berisiko yang efektif diperkenalkan bagi membantu para kontraktor mengurus secara sistematik risiko-risiko dalam penjadualan projek-projek merka.

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I certify that an Examination Committee met on 31 December 1999 to conduct the final examination of Anwar Mohammed Omer on his Master of Science thesis entitled "Time-Uncertainty Analysis by Using Simulation in Project Scheduling Networks" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree. The Committee Members for the candidate are as follows:

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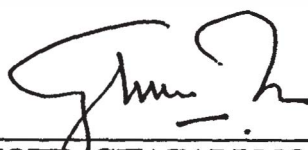
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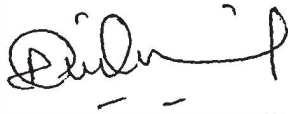
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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that this thesis has not been previously or concurrently submitted for any other degree at UPM or any other institutions.

Signed



Anwar Mohammed Omer

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CHAPTER 1

INTRODUCTION

Recent decades have been characterised by a vast proliferation of risk. The real scales of projects and investment programs have expanded dramatically, increasingly intractable geographical areas have been developed and economic instability in growth rates and prices have become endemic. With this uncertain and volatile environment, the need for risk management of potential projects and investment has increased (Cooper and Chapmann, 1987).

Project management is a discipline, which concerns itself with undertaking of projects to achieve some form of benefits. Within this discipline, there is an extensive body of knowledge about tools and techniques available for project management. Part of this body of knowledge must concern itself with how risks and uncertainties within a project can be analysed and managed. For many projects, additional information is needed to reduce risk and uncertainty to an acceptable level prior to their commencement. These factors increase the need for an early

assessment of the uncertainties and risks, which affect the project before large sums of money are irrevocably committed (Cooper and Chapmann, 1987).

A project risk is an implication of the existence of significant uncertainties about the level of the project performance. A source of risk is any factor that can affect a project performance, and risk arises when this effect is both uncertain and significant in its impact on the project performance. It follows that the definition of project objectives and performance criteria has a fundamental influence on the level of project risk.

Experience from many projects indicates poor performance in terms of achieving time and cost targets (Perry, 1986). Many cost and time overruns all occur due to either unforeseen events, which may or may not have been possible for experienced professionals to anticipate, or foreseen events for which uncertainty was appropriately accommodated. It is suggested that a significant improvement to project performance may result from a greater attention allotted to the whole process of risk management (Perry, 1986).

Laufer and Tucker (1988) concluded that uncertainty is not an exceptional state in the otherwise predictable process of construction

work. In fact it is a permanent feature in the realm of construction, obviously resulting from conditions prevailing at the construction site and its environment. By its very nature, there is no construction project that can be undertaken without an element of risk (Jaafari 1996; Ranasinghe, 1994; Gong and Hugsted, 1993; Chapmann 1991). Risk has been recognized as one of the most serious problems controlling the construction industry (William and Grandall, 1981; Cooper and Chapman, 1987).

Uncertainty is one of the problems faced by construction projects (Naoum, 1994). Uncertainty becomes important only when it affects the project objectives. When an uncertainty threatens to affect an objective of a project adversely, there exists a risk (Mawdesely, Askew, and O'Reilly, 1997).

Content of the Thesis

In chapter I, the problem background, objectives and scope of the study are illustrated together with the definitions of uncertainty, risk and risk management. The stages and constitution of risk management are also highlighted. In addition, a summarised list of risks associated with construction projects is mentioned.

Chapter II presents problems associated with the conventional PERT technique. The models and approaches developed to handle the merge event bias, which is the recognised problem of PERT, are also highlighted. A risk management framework known, as Construction Risk Management System (CRMS) is discussed as a logical substitute for traditional intuitive procedures currently used by most contractors. Also, the development of a simulation model is mentioned. This model is used to estimate the performance of the project objectives under the occurrence of the perceived risks. In addition to that, softwares recently developed to analyse risks associated with construction projects are also presented.

Chapter III illustrates the methodology used in this study, which is mainly based on simulation. Simulation is used in this study to test the standard PERT technique so as to explore the uncertainty and to quantify the risk associated with project scheduling. Also, simulation is used to ascertain whether there are any discrepancies in using the standard PERT technique in scheduling construction projects. In addition, simulation is used to assess the PNET and modified PNET approaches, which are developed to handle the merge event bias problem of conventional PERT technique. The PNET and modified PNET approaches are discussed in details in chapter II.

In chapter IV, Monte Carlo simulation as a stochastic computer model, which is used in this study is discussed. The generation variates and the mechanism of Monte Carlo concept are also illustrated. In addition to that, the selection of an appropriate distribution based on the concept of Monte Carlo is also interpreted.

Chapter V consists of two sections. In the first section, three case studies are presented using a simple scheduling project. Monte Carlo simulation is used to simulate the standard PERT technique so as to explore and quantify the opportunity or risk associated with a project scheduling. The magnitudes of bias of the three project networks are calculated. Moreover, the relative criticality of each activity in multiple path networks is indicated and hence the highest risk activities can be clearly nominated. The results and conclusions of the analysis are also presented.

In the second section, five case studies are presented. Monte Carlo simulation is used in this section to evaluate the following statements:

First, "for a project network, the likelihood completion date of a project is exactly equal to the product of the probabilities of each path, separately, with respect to a project completion date"; and

Second, "In a project network, if a path has a float greater than twice the larger standard deviation of this path and the critical path is dropped from the calculation of a project likelihood completion date, the bias correction in calculating the likelihood completion date of a project will be less than a few percent and can be ignored."

In chapter VI, an effective risk response framework is introduced to manage the risk associated with time scheduling in construction projects. This framework can be seen as a logical substitute for the traditional procedures currently used by contractors.

Chapter VII is the last chapter in this study. It mainly concentrates on conclusion, validity of the study and suggestion for further study.

Problem Background

PERT/CPM techniques are very common and widely adopted management tools currently used in the processes of project planning and control. These techniques have been widely accepted as the project planning tools in the construction industry. Despite of the use of these techniques, experience shows that construction projects fail to achieve their defined objectives with respect to time and cost (Jaafari, 1996; Gong